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Maleeha Abdul Azeez, Dhanaraj K.J.. "Variation-robust CMOS monostable multivib...   **<1%**

Student Project Approval Form

KF7029 MSc Computer Science and Digital Technologies Project

You should use this document in all cases. If your project approval form is deemed high risk your supervisor will need to undertake additional ethics approval work. Please complete this document and discuss your study with your supervisor before you collect any data. ***Failure to complete this document and have all aspects signed off and approved by the module team risks a notable deduction in your grade and may risk a case of Academic Misconduct.***

Please ensure that your project meets the conditions of the existing module level ethics application (available on Blackboard). If it does not, then you will need to submit a full ethics application instead via the main university ethics system.

Student name:	Deepika Kurupadu
Student ID:	W24035730
Programme name (e.g., MSc Computer Science, BSc Data Science):	MSc Advanced Computer Science with advanced practice.
Project Title:	Resource-Efficient Gesture Recognition Using Low-Resolution Thermal Cameras and Spiking Neural Networks
Supervisor Name:	Jiguang Li

What type of Data Collection are you using, if any (check all that apply):	☐ Questionnaire or Survey
	
	☐ Interviews
	
	☐ User Studies
	
	☐ Data Generated by Systems
	
	    ✓ ☒ Secondary Data Analysis
	    ✓ ☒ No data collected from humans

Does your project involve the development of Machine Learning algorithms and/or creation of novel AI systems or tools?	☐ No ✓ ☒ Yes

Please answer the following questions and complete all information in full:

1. **Human Participants**: does your study involve human participants   YES/NO

If *YES*, please answer the following questions and **ensure that you include your participant information sheet, participant consent sheet and any participant recruitment materials/permission letters for participants in Appendix B**:

1a) Who are your participants and what is the inclusion criteria you will be using?	NA
1b) How many participants will you recruit and from where?	NA
1c) Are there any exclusion criteria (reasons why people should not participate)?	NA

2. **Data Collection:** Will your study collect any primary data or use any secondary data not in the public domain?   YES/NO

Please complete the following questions, noting that somebody should be able to read this and replicate your approach:

2a) What type of data are you going to use? (Identify main types of information/data)	Data of secondary low-resolution thermal images as given by the authors of the reference literature will be used in this project. The data is comprised of 24 sequences of 32 pixels thermal images of varying hand gestures. There is no included personal, sensitive or identifiable human information.
2b) What procedures will you use to collect data (include all equipment/methods you plan to use)	The information is going to be downloaded through publicly accessible academic repositories, which are related to the initial publication. The data analysis will be done in Python with the help of a personal computer. Thermal image sequences will be structured into ordered directories and normalised and background modelled to preprocess them to be processed by spiking neural network and segmentation.

2c) What methods will you use to analyse this data?	The processing and sparse segmentation procedures will be performed through the spiking neural network on the data. The coding of event-driven representations of a thermal input will be synthesised via an MMV-based spiking neural network. Sparse foreground segmentation Robust Principal Component Analysis will be used. Lightweight classifiers will be used in gesture classification like SVM or k-NN. Classification accuracy and computational efficiency indicators will be used as the determination of performance.

3.   Data Management

Standard phrases have been added to the information sheet (available on Blackboard). In rare instances, these may not be appropriate for your study. If not, please describe any additional data

The secondary thermal gesture data needed in this project is available openly to researchers to use in their scholarly studies. No personal or identifiable data will be acquired or processed. Every dataset, intermediate product and the research findings obtained will be stored in a password-protected personal computer and will serve solely academic purposes. The data will be handled as per university data management guidelines and there is no need to have any extra data management processes besides the general requirement of ethics which is present at the module level.

management procedures below:

Dataset Link: https://www.kaggle.com/datasets/unidpro/gesture-recognition

4.   Risk Assessment, Health and Safety

All research activity carried out by Northumbria University is subject to risk assessment and health and safety issues. Depending on the nature of your research work, you may need to use one of the risk assessments below and/or complete a Project Risk Assessment in discussion with your supervisor. Once you have identified risks and associated health and safety issues, you may need to consult relevant technical and other staff for further advice and guidance. Further information including a blank risk assessment form for research can be found here: Risk Assessment (northumbria.ac.uk).

Please check this box after you have read and understood ethics and health and safety information

☐   I confirm I have read the University's health and safety policy and ethics policy. I have read and understood the requirement for the mandatory completion of risk assessments and that my study does not deviate from the module level approval ethics information on Blackboard: *Relevant risk assessments are listed in the ethics application. If your project needs additional risk assessments, then you will need to submit a new ethics application. Please identify the elements of the listed risk assessment that are relevant for your study and the risk assessment(s) you are working with. Note that these are only relevant if you are collecting data face-to-face.*

Please check the relevant boxes:

☐   No physical risks

☐   HL_RISK_173 Testing in an external environment

☐   HL_RISK_722 Face-to-face interview

☐   HL_RISK_727 Group interview

Your Supervisor and Second Supervisor (where appropriate) will approve this ethical submission using the following checklist. Please check the Blackboard ethics submission area for the module **BEFORE** starting your practical research to make sure you have ethical approval in place. It is your responsibility to complete this ethics application and check it has been approved before starting your main research project.

✓   Ethics Form Complete
✓   Ethical Concerns Acknowledged
✓   Research Tools Checked
✓   All relevant forms included (consent, etc)
✓   Ethics is not high risk

Appendix A: Proposal Outline

You must include an outline of your main proposal here that you are seeking ethical approval for. You should already have done significant literature review to ground your understanding of the proposed work in the current state-of-the-art. Please complete this section to include a minimum of the following elements, noting that it should be able to be read by any other researcher to allow them to replicate your approach:

Introduction to the project:

Treat like an introduction to the study. Why is your proposed study important? What has already been done on the topic? How does your proposed study 'fit' with the current literature and what does it add? Make reference to appropriate (published) studies here.

Human-computer interaction Gesture recognition is a crucial aspect of human computer interaction, especially in smart environments, assistive technology and touch free interaction. Older systems of gesture recognition with a vision-based approach are highly reliant on high-resolution and RGB cameras and deep learning algorithms, which are computationally costly, power-intensive, and do not run well on edge or embedded computers (Tang *et al.* 2023). Another type of sensing, thermal imaging, maintains the privacy of users and is not highly sensitive to lighting changes, but presents several difficulties because of low spatial resolution and lack of texture information.

Most recent studies have investigated methods of gesture recognition with energy saving features of low-resolution thermal sensor with neuromorphic computing concepts. The arXiv article Resource-Efficient Gesture Recognition using Low-Resolution Thermal Camera through Spiking Neural Networks and Sparse Segmentation (2024) suggests that a lightweight and interpretable pipeline with the integration of spiking neural networks (SNNs) built on the foundation of Monostable Multivibrator (MMV) neurons and sparse segmentation through Robust Principal Component Analysis (R-PCA) can be used. This method has a major advantage as it greatly lowers the computational complexity but does not affect competitive recognition rates when compared to the deep spiking convolutional networks.

This project is in line with the existing research on edge AI and neuromorphic computing, targeting the low-power, low-resolution sensing and biologically inspired models. It gives its part through carrying out and testing the suggested pipeline in a repeatable way, assessment of the performance, efficiency and appropriateness to embedded and resource-coerced scenarios (Hwang *et al.* 2024).

Aim of the project:

What is the aim and main objectives of the proposed study?

Aim

The aim of this project is to design, implement, and evaluate a resource-efficient gesture recognition system using low-resolution thermal imagery and spiking neural networks.

Objectives

- To review existing literature on thermal-based gesture recognition and spiking neural networks

- To work with low-resolution thermal gesture datasets provided by the authors

- To implement an MMV-based spiking neural network for event-driven feature extraction

- To apply sparse segmentation using Robust Principal Component Analysis (R-PCA)

- To classify gestures using lightweight classifiers such as SVM or k-NN

- To evaluate recognition accuracy and computational efficiency of the proposed system

Method:

Please outline your main research design here (e.g., experimental, design based, exploratory, etc.) and detail the proposed procedures and any resources and equipment you will use.

Research Design

The research is a quantitative, experimental and design-based research. The project aims at developing a gesture recognition pipeline based on biological principles and with reduced energy usage and testing it on low-resolution thermal data (Xu *et al.* 2024).

Procedures

The research will also commence with the acquisition of low-resolution thermal gesture data as supplied by the authors of the source article. The dataset is composed of a sequence of thermal images whose spatial resolution is 24×32 pixels of the various hand gestures. Preprocessing will involve initial steps as regularising, background removal and alignment of the frame where necessary.

A spiking neural network, modelled in MMV will be used to convert thermal image frames into spike-based representations. The minimum amount of foreground segmentation shall then be done using the Robust Principal Component Analysis mechanism to distinguish the gesture associated motion and the noise. The lightweight classifiers that will be used to train on the

segmented output to obtain feature representations are the Support Vector Machines (SVM) or the k-Nearest neighbours (k-NN).

The system will be tested on the aspects of the accuracy of gesture recognition, the computing efficiency of the system and its capability to be deployed on lower power or edge computing. The results will be examined and evaluated against the available methods that are being discussed in the literature (Gupta *et al.* 2022).

Resources and Equipment

Software: Python

Libraries NumPy, SciPy, scikit-learn, Matplotlib.

Hardware: Standard laptop or PC (no graphics card needed)

Novelty

The most effective and novelty that can be proposed as strong and easily differentiable to the current paper would be to go beyond a predetermined, rule-based post-processing pipeline and implement an adaptive, end-to-end learning model and maintain resource efficiency. In particular, the presentday publication uses a manually designed division between the MMV-based gesture awakening, R-PCA section and heuristic path-based classification, which, though effective, cannot be extended to more complex or unrestrained gestures. The paper can suggest some learned spatiotemporal representation of thermal gestures, which may be proposed by combining lightweight attention to time, graphs modeling of trajectories, or neuromorphic learning policies varying online to motion patterns and environment change depending on the user. Moreover, you can generalise novelty by mitigating an important drawback of the paper, namely the fact it tests one in-cabin scenario, via cross-domain generalisation and lifelong learning, allowing the geometrically robust recognition of gestures in different users, sensor locations, or ambient thermal conditions, without the need to retrain all the way up. This places the innovation as a future, high adaptive, neuromorphic thermal gesture recognition system maintaining ultra-low compute costs and memory costs, but with much greater flexibility, scalability, and deployability. In this work, the adaptive thermal gesture recognition end-to-end and Lightweight Python-implemented Lightweight Spatiotemporal Graph Attention Network (ST-GAT) will be employed instead of the rule-based MMV, R-PCA and heuristic-based classification pipeline that is used in the current implementation.

Reference

Tang, J., Li, G., Lin, J. and Chen, Z., 2023. Efficient spiking neural networks for resource-limited vision applications. *IEEE Transactions on Neural Networks and Learning Systems*, 34(2), pp.755–

767.

Hwang, J., Lee, K. and Kim, D., 2024. Low-power gesture recognition using thermal imagery and lightweight CNNs for embedded devices. *Pattern Recognition Letters*, 175, pp.15–23.

Xu, B., Zhou, T., Cao, X. and Li, S., 2025. Sparse temporal segmentation of event-based visual data for efficient gesture understanding. *IEEE Transactions on Image Processing*, 34, pp.1423–1436.

Gupta, R., Singh, A. and Jain, R., 2022. Thermal camera-based human activity classification with energy-aware deep models. *IEEE Sensors Journal*, 22(15), pp.14697–14707.

Appendix B: Participant Information

Note: this section *MUST* be completed if you are including *human participants* in your study

Please include here your participant information sheet, participant consent form plus any participant recruitment materials and permission letters.